12 July 2017

Denali Commission Award #01486-01
Environmentally Threatened Community Initiative, Phase 2.
Task Order #2, Statewide Threat Assessment Program Project

Quarterly Progress Report; April 2017 – June 2017

Summary

This project is a collaborative effort between the University of Alaska Fairbanks (UAF), the US Army Cold Regions Research and Engineering Laboratory (CRREL), and the US Army Corps of Engineers - Alaska District (USACE). USACE is responsible for identifying the risk from flooding and erosion. However, new work carried out by USACE will focus primarily upon flooding, because erosion was considered extensively in the 2009 Baseline Erosion Assessment. UAF, with assistance from CRREL, is responsible for evaluating the risk from thawing permafrost, as well as integrating the individual risks from coastal/riverine erosion, flooding, and permafrost degradation into a normalized, overall hazard index for each rural Alaska community with a year-round population greater than 20 (approximately 230 locations).

Progress This Quarter, April 2017 – June 2017

Project Meetings

UAF and CRREL team members held project meetings roughly every two weeks beginning 5/1/17. However, the final meeting of the quarter, scheduled for 30 June, was postponed until July. During these meetings, the team progressed on a number of separate tasks as described below:

Task-Based Progress

Task 1: Determine Permafrost Characteristics for Each Community. *Responsible Persons: Yuri Shur, Kevin Bjella, Andrew Balser and Misha Kanevskiy.*

Scope: Make a determination on the existence of permafrost for each community. Based on an initial review of existing data by UAF, there appear to be approximately 100 communities in areas which do not contain permafrost or the permafrost is thaw stable with little or no potential for thaw consolidation. However, it is anticipated that 130 - 150 communities will need detailed evaluation, and that approximately 65 locations will have high permafrost hazard. Existing geotechnical data will be used to estimate the ice content and potential thaw consolidation resulting from thawing permafrost.

Progress: A draft matrix has been developed describing permafrost-related characteristics for Alaska's communities. Information from this matrix is intended to inform the matric described

in Task 2 below. Currently, the matric has only been completed for five example communities (Please see Appendix Table 1).

Task 2: Inventory and Estimate the Potential for Damage Due to Thawing Permafrost*. Responsible Person: Il Sang Ahn*

An inventory of existing public infrastructure will be developed for each permafrost community using existing databases and other available information. Based on that inventory, damage to critical facilities will be estimated based on the risk of thaw consolidation. Damage estimates will be qualitative based on the amount of movement required to cause cosmetic damage, functional damage and structural damage. These estimates will be based on experience rather than structural analysis.

Progress: A draft matrix has been developed to describe the risk of damage to infrastructure based upon the permafrost characteristics, structure type, observed impacts, and other information derived from published sources or community input. Note that information gathered from Task 2 and Task 3 will likely be used in the completion of this matrix (Please see Appendix Table 2 and flow chart).

Task 3: Inventory Existing Damage Due to Thawing Permafrost*. Responsible Persons: Paul Perrault*

Communities expected to experience damage due to thawing permafrost will be contacted to confirm the inventory developed in Task 2, and to determine if existing infrastructure is showing damage due to thawing permafrost. Other relevant/responsible organizations such as ANTHC, ADEC, ADOT&PF, and regional health corporations will also be contacted. Phone and/or other off-site interview techniques will be used to determine whether the damage is cosmetic, functional or structural.

Progress: The team seeks to communicate with participating communities via telephone and a collaborative mapping exercise. We plan to ask Denali Commission to send out invitations (prepared by the team) to specific communities expected to experience significant observable threats from thawing permafrost. We believe that an invitation from Denali Commission would result in a higher response rate compared to a request from UAF that may be perceived as another research study. The invitation would direct interested parties to a website hosted on Denali Commission servers providing a general project overview, and asking interested parties to do three things:

1) Prepare for a phone call with our team by reviewing our material describing potential permafrost issues, and considering the extent to which those issues impact their community

2) Work with our team to schedule a phone call discussing the issues above. The phone call should include the person or people most knowledgeable on the topics.
3) Follow up the phone call by providing our team with relevant photos, marked-up maps, community plans, or other relevant documents.

Please see Community Information Outline (draft 6/23/17) in the appendix for more information regarding community data gathering. Our team seeks input from Denali Commission regarding this plan.

Task 4: Develop Scoring Criteria for Permafrost Vulnerability. *Responsible Persons: Billy Connor, Bill Schnabel, and Kevin Bjella*

Using the data assembled in Tasks 1 – 3 a scoring criteria similar to Hong, et. al. will be developed and applied to each community in order to rank them with respect to damage due to thawing permafrost. The scoring will account for the presence of permafrost, the potential for thaw consolidation, existing damage and anticipated future damage.

Progress: Draft scoring criteria for individual structure types are integrated into the Task 2 matrix. Those criteria range from 0 (no documented distress/risk) to 4 (major damage/extremely high risk). However, the team has not yet made progress on a procedure for assigning an overall score for communities.

Task 5: Combine Scoring From Erosion, Flooding and Permafrost Damage. *Responsible Persons: Billy Connor and Bill Schnabel*

Review erosion and flood data provided by USACE, draft scoring criteria developed by USACE for these two threats, and collaborate with USACE and the Denali Commission to develop a normalized, aggregate risk index for all three threats when considered together. Consider using a weighted matrix approach to create the final score. For example, existing or near term damage may have a higher weight than damage anticipated well into the future. Frequent flooding events may have a higher weight than events that may be expected to occur once every one hundred years.

Assist the Denali Commission in presenting the draft threat assessment methodology at public meetings at 2 – 3 locations outside of Anchorage, and with other interested government stakeholders such as Alaska DCCED, DNR, DOT&PF, DEC, and USDA, USDOC, FAA, BIA before finalizing the methodology.

Progress: No progress this quarter.

Task 6: Develop a GIS That Presents Data and Scoring. *Responsible Person: Andrew Balser*

Scope: Collaborate with USACE and the Commission on how best to store and present the flood, erosion and permafrost data assembled during the project, and the resultant vulnerability indices. At a minimum develop a query-able web-distributed data format (example Google Earth .kml file) that will present summary threat information for each community. Provide full GIS data (format suitable for download) to include the following information in a common format for Denali Commission.

- *Summary permafrost data (example: kml file(s) of village locations w tabular data)*
- *Detailed permafrost data (GeoDatabase, shape files, etc.) with provisions for flood*, and erosion* data*
- *Supporting geospatial imagery (public re-distribution of high-resolution, commercial satellite imagery is restricted under U.S. Federal Law, and by the auspices of the NextView contract between the U.S. Government and commercial imagery providers. Re-distribution determinations are made by U.S. National Geospatial Intelligence Agency (NGA)).*
- *Vulnerability index for each specific threat**
- *Aggregate vulnerability index**

** flood and erosion data and corresponding threat indices for each community are to be developed by the U.S. Army Corps of Engineers Alaska District in Anchorage as a separate section of the project as complete, georeferenced vector and/or raster GIS datasets with metadata and description of data development.)*

Progress: No progress this quarter.

Task 7: Reporting *Responsible Persons: Billy Connor, Bill Schnabel, and Kevin Bjella*

Scope: Separate final reports will be prepared summarizing the work related to permafrost and the overall aggregate risk methodology. The permafrost report will describe the data, data sources, and interpretation of the data. It will also describe the scoring criteria for the permafrost index and results by community. The second report will summarize the methodology developed that combines all three threats. The report will also include a description of the GIS, layer structure, the data table associated with the GIS, and a summary of the knowledge/data gaps that should be addressed in future updates.

Progress: No progress this quarter.

Task 8: Presentation *Responsible Persons: Billy Conner and Bill Schnabel*

Scope: A presentation of the final work products will be given at a mutually acceptable time and location to the Denali Commission.

Progress: No progress this quarter.

Future Work

In the upcoming quarter, the team will continue to focus on Tasks 1-3, as well as develop the technology/methodology for Task 6.

Please contact me with any questions or concerns,

William Schnabel, PhD, PE
Director, UAF Institute of Northern Engineering

Appendix

Table 1. ***Data required for general assessment of permafrost conditions in Alaskan villages and risk evaluation for permafrost-related hazards (example)***

Village	Permafrost (PF) zone and PF thickness	PF occurrence[2]	PF temperature (MAGT), °C	Active-layer (AL) thickness, cm; PF table, m (for locations with lowered PF table)	Soils, gravimetric moisture contents (GMC), excess ice volume (EIV), etc.	Thickness of layer with excess ground ice (H), m	Thaw strain (T), unit fraction	Massive ice: Wedge-ice volume (WIV), unit fraction; height of ice wedges (HIW), m	Thaw settlement (TS), m [3] TS = WIV*HIW*(1–T) + T*H	PF features detected on sat. imagery[4]	Existing hazards: Hazard Mitigation Plans; pers.com., etc.[5]
1	2	3	4	5	6	7	8	9	10	11	12
Wainwright	Continuous ~300 m	P	-8	20-50	Ice- and org-rich silt (4.5-6 m thick) underlain by sand and gravelly sand	6	0.5	WIV: 0.2 HIW: 4	3.4	HCP – high surface; LCP – thaw-lake basins; TP&TG – rare; TLB	Half of all the ice cellars in Wainwright have been lost in the last 30 years; problems with foundations were reported (Wainwright Comprehensive Plan, 2014).
Kaktovik	Continuous ~400 m	P	–9	30-50	Ice-rich peat, sandy silt with ice wedges (2.5 m), sand and gravelly sand with massive ice (7 m), underlain by marine clay	>9	0.3	0.35 (WI + buried glacier ice), H=HIW	4.9	HCP – high surface; LCP – thaw-lake basins; TP, TG; TLB	Houses and other buildings are beginning to settle, with floors and structures now becoming uneven (Kaktovik LHMP, 2005).
Kaltag	Discont., 20 m	PTL	–0.5	AL: 40-100, PF: 2-7.5	Organic silt, silt, sporadically - sand and gravel; GMC of frozen silt up to 40%	5?	<0.05	No massive ice	0.2	Shallow TLB in the forests adjacent to the village	The new town site development area has approximately 14 homes that are experiencing uneven settlement (thawing) or uplift (frost heaves). These incidents are directly related to human induced thawing and refreezing permafrost conditions. Uneven settling throughout the years within the City has damaged other buildings and roads constructed in permafrost areas (Kaltag HMP, 2010).
Emmonak	Discont., >10? m	PTL	–1	AL: 40->100, PF: 1.5-3.0	Floodplain and deltaic deposits (silt, sandy silt, GMC <50%, EIC up to 40% but mostly 0 to 10%) with thin organic cover	10?	0.05	No massive ice	0.4	Thermokarst ponds and bogs near the village; no distinct ice-wedge polygons	Ground failure events have not been officially documented in Emmonak. However, the community is located within an area of continuous permafrost and does experience ground subsidence and heaving (Emmonak LHMP 2014).
Tunanak	Sporadic, ? m	TL ?	–0.5	?	Sand, gravel - ????	?	?	No massive ice	?	Thermokarst ponds and bogs near the village; no distinct ice-wedge polygons	There have been ground failure incidents in Tununak from subsidence (Tununak 2015)

Table 2. ***Evaluation system for permafrost-related hazards: categories*** **(A and B)** ***and levels*** **(0 to 4)**

A. Existing Permafrost-Related Problems				**B. Risks of Future Permafrost Degradation and Thaw Settlement**					
AI. Natural hazards: Thermokarst and thermo-erosional processes, detected by analysis of aerial photos and satellite imagery	***AII. Documented Distress based on communication with community and maintenance personnel; analysis of existing reports and publications***			***BI. Risk of permafrost degradation (depends on ground temperatures only)***	***BII. Risk of thaw settlement (TS) of the ground surface during anticipated life of infrastructure as a result of permafrost degradation (occurs when MAGT > 0°C)***				***BIII. Risk of differential TS > 1 m due to ice-wedge thawing (not necessarily related to general TS caused by PF degradation when MAGT exceeds 0°C)***
	AIIa. Structures including schools, power plants, water / wastewater treatment plants, clinics	**AIIb. Utilities including water / wastewater transmission, power transmission, etc.**	**AIIc. Transportation including roads, streets and airports**		**BIIa. For structures with shallow foundations** **Life = 50 years**	**BIIb. For structures with deep foundations** **Life = 50 years**	**BIIc. For utilities** **Life = 30 years**	**BIId. For roads and airports** **Life = 20 years**	
0. No detected permafrost features	**0. No documented distress**			**0. No risk** No permafrost					
1. Minor hazards No active thermokarst and thermo-erosional features, rare relic inactive features may be detected (e.g., vegetated thermo-erosional gullies, depressions of possibly thermokarst origin)	**1. Minor Cosmetic Damage**	**1. Minor distress to include minor movement with no loss of service**	**1. Minor distress which results in occasional maintenance and loss of service**	**1. Low** MAGT < -5°C	**1. Low** TS < 0.05 m	**1. Low** TS < 0.1 m	**1. Low** TS < 0.05m	**1. Low** TS < 0.2 m	**1. Low** Inactive ice wedges buried by thaw-stable permanently frozen soils >1 m thick
2. Moderate hazards Ice-wedge polygons with rare small thermokarst ponds, rare moderately active thermo-erosional gullies	**2. Major Cosmetic Damage**	**2. Minor Damage requiring occasional shoring or minor repairs to restore service repair**	**2. Distress requiring occasional maintenance beyond routine**	**2. Moderate** MAGT = -5 – -2°C	**2. Moderate** TS = 0.05 – 0.1 m	**2. Moderate** TS = 0.1 – 0.5 m	**2. Moderate** TS = 0.05 – 0.1 m	**2. Moderate** TS = 0.2 – 1.0 m	**2. Moderate** Small inactive or moderately active ice wedges
3. Major hazards Wide-spread ice-wedge polygons with numerous shallow thermokarst ponds above degrading ice wedges, active thermo-erosional gullies	**3. Minor Structural Damage**	**3. Major damage requiring frequent shoring and major repairs to restore service**	**3. Distress requiring frequent maintenance to insure service**	**3. High** MAGT = -2 – 0°C	**3. High** TS = 0.1 – 0.5 m	**3. High** TS = 0.5 – 1.0 m	**3. High** TS = 0.1 – 0.3 m	**3. High** TS = 1.0 – 2.0 m	**3. High** Medium size moderately active ice wedges
4. Extreme hazards Active thaw slumps with exposed ice-rich permafrost, numerous deep thermokarst ponds above large degrading ice wedges, deep active thermo-erosional gullies	**4. Major Structural Damage**	**4. Major damage resulting in prolonged loss of service**	**4. Distress resulting in loss of service and major repairs**	**4. Extremely high** Permafrost is currently degrading; MAGT > 0°C	**4. Extremely high** TS > 0.5 m	**4. Extremely high** TS > 1.0 m	**4. Extremely high** TS > 0.3 m	**4. Extremely high** TS > 2.0 m	**4. Extremely high** Large active ice wedges near the surface

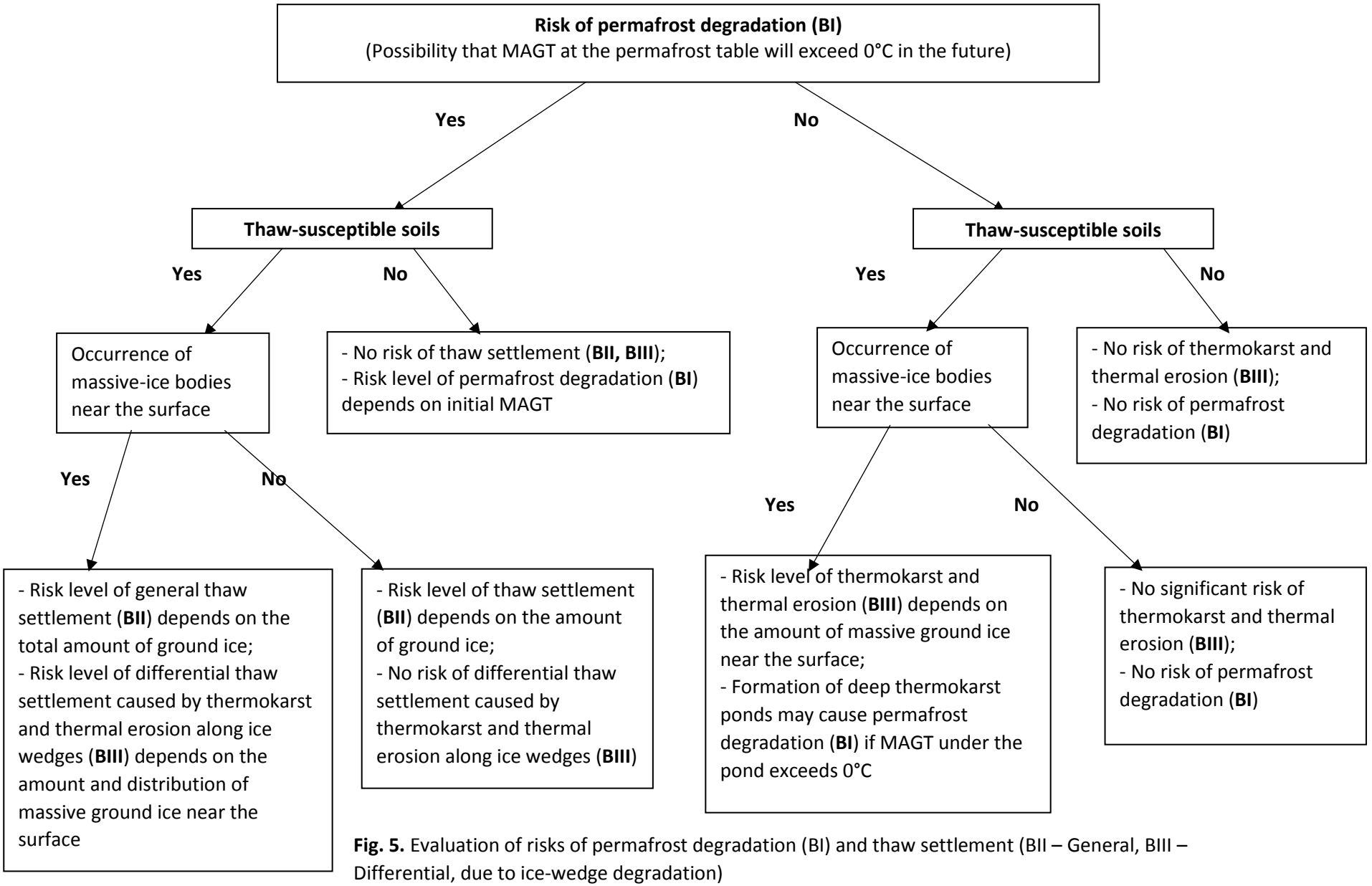

Fig. 5. Evaluation of risks of permafrost degradation (BI) and thaw settlement (BII – General, BIII – Differential, due to ice-wedge degradation)

Community Information Outline

Draft 6-26-17

Purpose:

We want to outline next steps regarding sending out and receiving information from communities. The basic plan is to ask Denali Commission to send invitations to all of the communities. The invitations will direct community members to a website that contains a project info packet, as well as maps specific to each community. Following their review of the info packet, then our team will contact community members for community-specific questions.

Info Packet Contents:

-Provide overview of who we are/Denali Commission (UAF is doing this on behalf of DC)

-Provide overview/goals of the entire project

-Explain that we are performing the permafrost portion of the project

-Explain what are the benefits to the community for participating

-Provide more detailed information about our objectives. Specifically: We want to gather information from community regarding vulnerability of community to thawing permafrost. We will use past and present conditions as a predictor of future issues. We not only want to know about specific issues they've seen, but we also want to know as much as we can about the extent to which their community was constructed to accommodate permafrost and potential permafrost changes.

-Explain to them where they can get the results of the project work (Direct them to Denali Commission website or something), or alternatively commit to sending a copy of project results directly to the participants.

-Tell them specifically what we want for them to do as part of the project. This includes the following three items:

1) We want them to prepare for a phone call with us by reviewing our material describing permafrost issues, then considering whether those issues impact their community.
2) We want them to participate in a scheduled phone call with us to discuss the issues above. The phone call should include the person or people most knowledgeable on the topics.
3) We want them to follow up the phone call by providing our team with relevant photos, marked-up maps, community plans, or other relevant documents.

-Provide an informational overview so that people know what conditions we are asking about. We need to explain thawing permafrost-related issues – (mild, moderate or severe), and provide example pictures. We should use Misha's risk matrix as a guide. We also want to provide a map of each community that people can look at and mark up (using a common nomenclature). Also, we will ask them to consider their own infrastructure, and provide them pictures or descriptions of infrastructure issues/damage broken down according to the following categories:

Categorize descriptions/questions into three categories:

1) Structures including schools, clinics, power plants, water / wastewater treatment plants, fuel storage facilities
    a. Obvious settlement of soil upon which structure is placed (first of all, differential settlement)
    b. Ponding in settled soil around structure
    c. Snow drifts in settled areas
    d. Flowing water through areas that aren't designed to contain flowing water
    e. Are their some detached foundation elements
    f. Do the doors and windows close properly
    g. Are the floors level
    h. Is there cracked drywall (or separation between walls/floor/ceilings)

2) Utilities including wastewater lagoons, water supply
    a. Utility breaks that have occurred
        i. Utility break at structure
        ii. Utility break between structures
    b. Water supply pond or wastewater lagoon containment break
    c. Settlement around water and/or fuel storage tanks
    d. Loss of functionality due to permafrost-related movements (thaw settlement, frost heave, thermal erosion)

3) Roads/Runways
    a. Are we seeing differential settlement? How rough is the road/runway?
    b. Are we seeing sloughing sideslopes?
    c. Malfunctioning or deformed culverts?
    d. Ponding at toe of sideslopes?
    e. Does road/runway require frequent grading/filling?
    f. If paved, do roads/runways require frequent asphalt patching?

Note – the above items are things we would provide to the communities before we do the interview questions with them. Most of this information would be common to all communities. However, we should provide specific maps of each community for folks to download. Maps can be obtained at the following address or other sources
http://dcced.maps.arcgis.com/apps/Viewer/index.html?appid=8e346292c8df44fa98b7d80740c67b03

Then the actual interview questions should be tailored to a similar organizational scheme as that described above (i.e., three general types of infrastructure issues (structural, utilities, and roads/runways).